International Journal of Electrical and Electronics
Engineering Research (IJEEER)
ISSN (P): 2250-155X; ISSN (E): 2278-943X
Vol. 3, Issue 5, Dec 2013, 29-38

ANALYZING THE IMPACT OF ROOFTOP RENEWABLE ENERGY ON DISTRIBUTION SYSTEM WITH MONTE CARLO SIMULATION

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ABSTRACT

In developing countries energy demand is steadily increasing at a pace which is not met by the conventional sources alone. This is particularly noticeable in developing countries like India. Non conventional energy or renewable energy which is a clean, environment friendly sustainable source of energy freely obtainable from nature, should play a vital role in meeting the energy needs of the country. India is witnessing a rapid growth in solar and wind energy sector. Recently MNRE (Ministry of New and Renewable Energy sources) stressed on the roof top power generation in their policy document. Estimating the actual power generated by a roof top energy system with wind and solar power needs attention. Though several methods are available in literature they need large number of samples. In this paper an attempt has been made to estimate potential of wind and solar simultaneously using Monte Carlo simulation technique. Effective load is also computed and load flow analysis is performed for a typical residential feeder.

KEYWORDS: Renewable Energy, Monte Carlo, Roof Top Energy

INTRODUCTION

Energy plays a critical role in the growth of economy and. in improving the quality of life. World energy outlook summary states that a whooping 80% of the total energy generated in the world is from fossil fuels like coal, gas and oil. Use of Fossil fuels causes green house gas emissions particularly carbon dioxide which leads to global warming. In the Indian context, it is estimated that the energy demand will raise to about 3 times the present demand by2020 In India 50% of commercial energy production is done by coal Inspite of low per capita consumption when compared with other developed countries the contribution of carbon dioxide emission is about 4% of total world as on now. The climatic change not only effects human habitat but also eco systems. The need of the hour is to increase generation which is environment friendly and affordable [1]. N.K. Sharma et al [2] estimated that 1GW of additional power generation by renewable energy sources reduce emission of carbon content by 3.3 million tons a year. To fill up the supply demand gap the country is looking towards alternate sources of energy. These sources augment the energy supply as well as help in mitigating the climatic change. Solar and wind are most popular among the renewable energy sources and are playing an important role in bridging the supply demand gap. The Ministry of New and Renewable Energy Sources (MNRES) is taking several measures to promote these resources.

SOLAR ENERGY

This is an alternate energy source with zero emission and has minimum maintenance cost. In India, with its vast open lands, the solar energy potential is estimated to be about 5 Peta Watt hours per year (5 trillion kWh) which is huge in terms of the present energy consumption.

WIND ENERGY

Wind farms have become very popular due to the tremendous development in related technologies. The very low gestation periods, high reliability and excellent performance made wind a viable alternative for energy capacity addition in India. Wind energy is viable in many parts of the country and at present only a faction of potential is being tapped.

ROOF TOP ENERGY GENERATION

To install large grid connected generation large areas are required for alternate energy sources. Centre for study of science, technology and policy mentions that for example a 50 MW renewable energy generating station may require about 100 hectares of land where as a gas base station require only 1to 2 hectares Instead of constructing large generation farms it is convenient to install small energy centers particularly on roof tops which can produce small amounts of energy needed for a house. Small scale roof top systems have several advantages.

- No additional useful land is needed
- Minimized of transmission and distribution losses
- Fossil fuel consumption which leads to pollution is reduced
- Reliance on the grid is reduced

Estimating the roof top energy potential is very cumbersome and time consuming. M. Arshad Javaid et. al [3] conducted experiments on solar power modules throughout the day in PCSIR laboratory, Lahore, Pakistan and found that the results are useful for implementation of smart grid technology in Pakistan. M. Bindi et al [4] estimated daily global radiation using the data of maximum and minimum temperatures and the total rain fall. Dimas Firmanda Al Riza et al [5] predicted hourly solar radiation data using two methods. In the first method a decision matrix is used from the measured values of relative humidity and temperature data. The second method is done by taking into account the relative humidity clearness index, relative humidity correlation etc. Iranna Korachgaon et al [6] estimated global solar radiation for different places in Brazil using parameters like ambient temperature, humidity, wind speed, moisture etc with the Iranna- Bapat's model proposed by them. A ten parameter model and a two parameter models were developed and results they got are about 90% accurate. A. M. Muzathik et al [7] collected different empirical models that are available to estimate average daily global radiation in Terengganu in Malasia.T hey compared the models that were collected taking into account the statistical error tests like mean bias error, root mean square error etc and modified Angstrom model is recommended for predicting average daily global radiation. V. K. Marwal et al [8] employed six empirical relations and predicted daily solar radiation for jaipur India.

They found that cubic correlation is the best. Rizwan M et al [9] Proposed Generalized Neural Network technique [GNN] to estimate solar energy accurately. Tamer Khatib et al. [10] predicted global solar energy estimation using feed forward multilayer perception model in Malasia taking latitude, longitude, day number and sunshine ratio and found that error is around 7.96%. Ibeh G.F et al [11] compared Multi layer Perceptron ANN model and Angstrom – Prescott using four parameters maximum temperature, relative humidity, cloudiness and sunshine duration for Warri- Nigeria for prediction of solar radiation and concluded that ANN model is better. Emad A. Ahmed et al [12] Used ANN technique to predict solar radiation and compared with the available empirical regression models and found it to be more suitable. N. Premalatha et al[13] used Gradient descent back propagation with adoptive learning rate ANN for predetermining global solar radiation. However it can be used for locations where data of ambient temperature is available.

The literature survey also has been done for estimation of wind energy. J. V. Seguro et al [14] presented and compared three methods for finding Weibul parameters for distribution of wind speed to estimate wind energy. The methods include maximum likelihood method, general graphical method and modified MLH method. They observed that maximum likelihood method is suitable for usage with time series wind data and modified likelihood method for wind data in format of frequency distribution Nabiha Brahmi et al [15] developed a method Using ANN called optimized maximum Likelihood method. This algorithm is used to find out wind energy potential of SFax city, Tunisia. S. Vijaya Venkataraman et al. [16] analyzed the data of wind speed for 15 stations in India randomly for the year 2009 and identified in which months maximum energy can be harnessed. Tian Pau Chang [17] proposed two probability functions namely Mixture Gamma–Weibull function and mixture truncated normal function and compared with methods that are already available. Three wind farms under different weather conditions in Taiwan are considered and concluded that the proposed GW method is superior to other methods. Kobayashi. Y et al [18] estimated the total potential of wind energy in the world by beginning of 22 century. They considered world population to be 13billion and predicted that 7.75 of world energy demand will be met by wind. Abbes D et al [19] estimated wind energy for different sites using Weibull distribution and direct integrated methodology. Results indicated that the latter method was accurate.

For assessing wind power, wind power distribution (WPD) curve is necessary. Mark L. Morrissey et al. [20] proposed a new method for directly estimating the curve using Gauss–Hermite expansion which provides a reliable WPD curve

Above literature survey indicates that this requires data of previous years with the required time interval and the accuracy of the method depends on the number of samples (years). In many cases the data at this granularity may not be available, but hourly average data should be available easily, which is not sufficient for Weibull method. In this paper, Monte Carlo Simulation is used to estimate the wind and solar energy simultaneously at a given time. This energy is considered while computing the profile of a distribution system. The proposed method can be extended to any number and type of source of energy.

MONTE CARLO METHOD

Broadly Monte Carlo principle states that random events with equal probability produce similar results when the number of trials tends to infinity. Monte Carlo Simulation refers to a typical simulation which depends on repeated random samplings and statistical analysis to find results. A literature survey has been carried out taking renewable energy applications using Monte Carlo approach into account

Samik Ray Chaudhuri [21] described in detail about Monte Carlo simulation and discussed about mathematical techniques that are involved and presented examples from various Engineering disciplines where MCS is used which includes electronic engineering, mechanical engineering etc. Halamay D A [22] used the WSCC/WECC 179 bus system to find out feasibility of combining solar, wind and ocean wave generation with existing base generation using Monte Carlo analysis and discussed about the importance of alternate energy sources. Hopkins. M. D et al [23] developed a method for predicting energy production by solar and wind using Monte Carlo based method. Billinton. R [24] proposed a sequential Monte Carlo Simulation method for generation of capacity adequacy simulation of small stand alone wind energy conversion system applicable to rural areas using battery storage. Amir Saf darian et al[25] proposed a novel formulation for optimal sizing of wind and solar resources in hybrid generation system. The decision variables include number of wind turbines, solar modules to be introduced and also uncertainties associated with load, wind speed, solar irradiation. Monte Carlo simulation is used to generate different scenarios. Grigorios Marmidic et al [26] introduced a novel procedure for

optimal placement of wind turbines using Monte Carlo simulation method. The optimization took into account maximum energy production and minimum cost criteria. Su Youli et al [27] proposed a reliability evaluation of laboratory base micro grid consisting of wind, solar, diesel generator with storage batteries using Monte Carlo simulation for system well being analysis

PROBLEM FORMULATION

In this paper, an attempt is made to use Monte Carlo (MC) method to simulate the available power.

$P_m = P_a \times (1 + \Delta p)$

Where

P_m is the power estimated with Monte Carlo Method

P_a is the average power obtained from known data

Δp is a random variable that represents the variation from average (as a percentage) for which value is obtained using MC simulation

P_t = sum for day = 1 to 365 (sum for hour = 0 to 23 (P_m))

Where P_t is total estimated harvested energy

$L_e = L_a - L_g$

Where L_e is the effective load, L_a is actual load and L_g is generated (rooftop) load.

$|V_{(i+1)}| = [(P_{(i+1)} R_{(i)} + Q_{(i+1)} X_{(i)} - 0.5|v_{(i)|}2)^2 - (R_{(i)}^2 + X_{(i)}^2)(P_{(i+1)}^2 + (Q_{(i+1)}^2) - (P_{(i+1)} R_{(i)} + Q_{(i+1)} X_{(i)} - 0.5|v_{(i)|}2)]^{1/2}$

$LP_{(i)} = R_{(i)} (P_{(i+1)}^2 + Q_{(i+1)}^2) / (|V_{(i+1)}|)^2$

$LQ_{(i)} = X_{(i)} (P_{(i+1)}^2 + Q_{(i+1)}^2) / (|V_{(i+1)}|)^2$

The data of a typical residential feeder is obtained from the Utility Company for which the data is as follows:

Feeder length is approximately 1 km with laterals at various places. For simplicity, the feeder is assumed to have uniformly distributed load and the laterals are reduced to 10 with a length of one km each. Considering each house with a width of 10 to 15 meters, it can be fairly assumed that there are about 1000 houses per feeder. The feeder has (R +JX) ohms/km. The following is the line diagram of the feeder with above assumptions:

Weasel conductor has been used for calculations. We have considered 10 Bus with the given types of loads (Monte Carlo load data and Average load data) with equal load sharing by each bus with a span of 60 meters between buses. Resistance and Reactance per Km are taken to be 0.908Ω and 0.314Ω respectively for Weasel conductor. Figure 1 Represents a 10 bus system

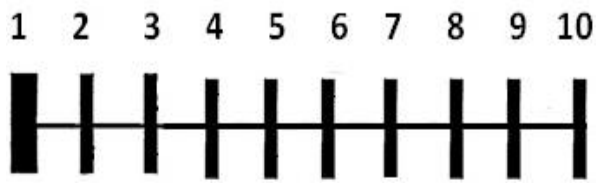

Figure 1: Bus Distribution Network

Since load varies with season, effective load for each hour of each month is considered.

MONTE CARLO METHOD

Broadly Monte Carlo principle states that random events with equal probability produce similar results when the number of trials tends to infinity. In this paper, the bell shape probability distribution of variation from median is approximated to discrete ranges as follows:

Variation can be up to 25% (-12 to +13%) from the average value

For 50% of times, variation is 10% (+/- 5%)

For 30% of times, variation is 15% (-7 to +8%)

For 10% of times, variation is 20% (-10 to +10)

For 10% of times, variation is 25% (-12 to 13%)

These ranges are taken considering the weather will not change considerably with respect to the average (taken over about 30 years). As the proposed method is a framework, the values, the deviations etc can be changed according to the conditions under consideration.

The number of trials should be fairly high to get reliable correlation between the actual and simulated value. In this case it is taken as 10000 as it gave the nearest values. Figure 2 shows the frequency of variation with number of trials.

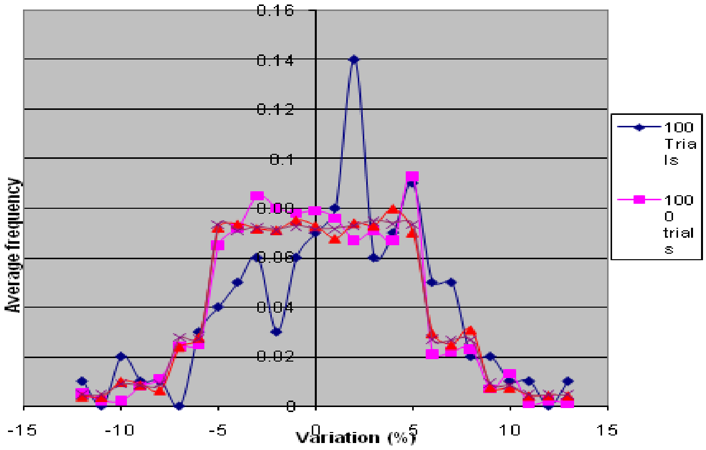

Figure 2: Number of Trials vs Frequency of Variation

EFFECTIVE LOAD PREDICTION ALGORITHM

Initialize

P_{sa}[m][h] //monthly hourly average solar power available in Watts

P_{wa}[m][h] //monthly hourly average wind energy available in Watts

L[m][h] //monthly hourly average actual load (Watts)

For iteration i= 1 to 10000

For each month m

For each hour h

R_s = Random Variable within (+/- 15%) for solar

R_w = Random variable within (+/- 15%) for wind

P_s = psa[m][h]*(1+R_s) //estimated solar power available in that month and hour

P_w= pwa[m][h]*(1+R_w) //estimated wind power available in that month and hour

L_e = L[m][h]-(P_s+P_w) //effective load at that month and hour

Once the effective load is computed using Monte Carlo Method, load flow analysis is performed and the improvement can be observed. A negative power indicates a power reversal, where the consumer gets energy points which can be redeemed at a later time. Figure 3 shows the actual and MC simulated average loads. It can be observed that there is hardly any difference between actual and MC results and hence, only 4 curves are seen since the original values are matching with the simulated values. Tables 1 & 2 are the Monte carlo load and average load profiles for the 10 bus system considered

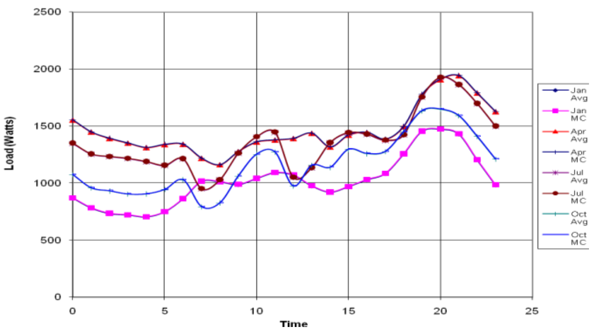

Figure 3: Hourly-Monthly Average and MC Loads

Table 1: Monte Carlo Loads for 10-Bus System

HOUR	0	1	2	3	4	5	6	7	8	9	10	11
V1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V2	0.9994	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9994	0.9994
V3	0.9989	0.9990	0.9990	0.9991	0.9991	0.9991	0.9990	0.9991	0.9991	0.9990	0.9989	0.9988
V4	0.9985	0.9986	0.9986	0.9987	0.9987	0.9987	0.9986	0.9987	0.9987	0.9985	0.9984	0.9984
V5	0.9981	0.9982	0.9983	0.9983	0.9984	0.9983	0.9982	0.9984	0.9984	0.9982	0.9980	0.9979
V6	0.9978	0.9979	0.9980	0.9981	0.9981	0.9980	0.9979	0.9982	0.9981	0.9979	0.9977	0.9976
V7	0.9975	0.9977	0.9978	0.9978	0.9979	0.9978	0.9977	0.9980	0.9979	0.9976	0.9975	0.9973
V8	0.9973	0.9975	0.9976	0.9977	0.9977	0.9977	0.9975	0.9978	0.9977	0.9974	0.9973	0.9971
V9	0.9972	0.9974	0.9975	0.9976	0.9976	0.9975	0.9974	0.9977	0.9976	0.9973	0.9971	0.9970
V10	0.9971	0.9973	0.9974	0.9975	0.9976	0.9975	0.9974	0.9976	0.9976	0.9973	0.9971	0.9969
PLOSS	**2.3395**	**1.9964**	**1.8417**	**1.7637**	**1.6956**	**1.7897**	**1.9868**	**1.5700**	**1.6812**	**2.1147**	**2.4479**	**2.6817**
QLOSS	**0.8090**	**0.6904**	**0.6369**	**0.6099**	**0.5864**	**0.6189**	**0.6871**	**0.5429**	**0.5814**	**0.7313**	**0.8465**	**0.9274**

HOUR	12	13	14	15	16	17	18	19	20	21	22	23
V1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V2	0.9995	0.9994	0.9994	0.9994	0.9994	0.9994	0.9993	0.9992	0.9992	0.9992	0.9993	0.9994
V3	0.9990	0.9989	0.9989	0.9989	0.9988	0.9988	0.9987	0.9985	0.9984	0.9985	0.9986	0.9988
V4	0.9986	0.9985	0.9985	0.9984	0.9984	0.9984	0.9982	0.9979	0.9978	0.9979	0.9981	0.9983
V5	0.9982	0.9981	0.9981	0.9980	0.9980	0.9980	0.9978	0.9974	0.9972	0.9973	0.9976	0.9979
V6	0.9980	0.9978	0.9978	0.9977	0.9976	0.9976	0.9974	0.9969	0.9968	0.9969	0.9972	0.9975
V7	0.9977	0.9976	0.9975	0.9974	0.9974	0.9973	0.9971	0.9966	0.9964	0.9965	0.9969	0.9973
V8	0.9975	0.9974	0.9973	0.9972	0.9972	0.9971	0.9969	0.9963	0.9961	0.9963	0.9966	0.9971
V9	0.9974	0.9973	0.9972	0.9971	0.9970	0.9970	0.9967	0.9961	0.9960	0.9961	0.9965	0.9969
V10	0.9974	0.9972	0.9972	0.9970	0.9969	0.9969	0.9967	0.9960	0.9959	0.9960	0.9964	0.9968
PLOSS	**1.9640**	**2.2099**	**2.2824**	**2.5576**	**2.6363**	**2.6609**	**3.1531**	**4.4210**	**4.8231**	**4.5691**	**3.6641**	**2.8128**
QLOSS	**0.6792**	**0.7642**	**0.7893**	**0.8845**	**0.9117**	**0.9202**	**1.0904**	**1.5288**	**1.6679**	**1.5801**	**1.2671**	**0.9727**

Table 2: Average Loads for 10-Bus System

HOUR	0	1	2	3	4	5	6	7	8	9	10	11
V1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V2	0.9994	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9994	0.9994
V3	0.9989	0.9990	0.9990	0.9991	0.9991	0.9991	0.9990	0.9991	0.9991	0.9990	0.9989	0.9988
V4	0.9985	0.9986	0.9986	0.9987	0.9987	0.9987	0.9986	0.9987	0.9987	0.9985	0.9984	0.9984
V5	0.9981	0.9982	0.9983	0.9983	0.9984	0.9983	0.9982	0.9984	0.9984	0.9982	0.9980	0.9980
V6	0.9978	0.9979	0.9980	0.9981	0.9981	0.9980	0.9979	0.9982	0.9981	0.9979	0.9977	0.9976

V7	0.9975	0.9977	0.9978	0.9978	0.9979	0.9978	0.9977	0.9980	0.9979	0.9976	0.9975	0.9973
V8	0.9973	0.9975	0.9976	0.9977	0.9977	0.9977	0.9975	0.9978	0.9977	0.9975	0.9973	0.9971
V9	0.9972	0.9974	0.9975	0.9976	0.9976	0.9975	0.9974	0.9977	0.9976	0.9973	0.9971	0.9970
V10	0.9971	0.9974	0.9975	0.9975	0.9976	0.9975	0.9974	0.9976	0.9976	0.9973	0.9971	0.9969
PLOSS	**2.3289**	**1.9877**	**1.8337**	**1.7561**	**1.6887**	**1.7822**	**1.9794**	**1.5638**	**1.6747**	**2.1056**	**2.4372**	**2.6703**
QLOSS	**0.8054**	**0.6874**	**0.6341**	**0.6073**	**0.5840**	**0.6163**	**0.6845**	**0.5408**	**0.5792**	**0.7281**	**0.8428**	**0.9234**

HOUR	12	13	14	15	16	17	18	19	20	21	22	23
V1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V2	0.9995	0.9994	0.9994	0.9994	0.9994	0.9994	0.9993	0.9992	0.9992	0.9992	0.9993	0.9994
V3	0.9990	0.9989	0.9989	0.9989	0.9988	0.9988	0.9987	0.9985	0.9984	0.9985	0.9986	0.9988
V4	0.9986	0.9985	0.9985	0.9984	0.9984	0.9984	0.9982	0.9979	0.9978	0.9979	0.9981	0.9983
V5	0.9982	0.9981	0.9981	0.9980	0.9980	0.9980	0.9978	0.9974	0.9973	0.9973	0.9976	0.9979
V6	0.9980	0.9978	0.9978	0.9977	0.9976	0.9976	0.9974	0.9969	0.9968	0.9969	0.9972	0.9976
V7	0.9977	0.9976	0.9975	0.9974	0.9974	0.9973	0.9971	0.9966	0.9964	0.9965	0.9969	0.9973
V8	0.9975	0.9974	0.9974	0.9972	0.9972	0.9971	0.9969	0.9963	0.9962	0.9963	0.9966	0.9971
V9	0.9974	0.9973	0.9972	0.9971	0.9970	0.9970	0.9967	0.9961	0.9960	0.9961	0.9965	0.9969
V10	0.9974	0.9972	0.9972	0.9970	0.9970	0.9969	0.9967	0.9961	0.9959	0.9960	0.9964	0.9969
PLOSS	**1.9564**	**2.2011**	**2.2733**	**2.5470**	**2.6250**	**2.6496**	**3.1396**	**4.4021**	**4.8020**	**4.5504**	**3.6492**	**2.8024**
QLOSS	**0.6765**	**0.7612**	**0.7861**	**0.8808**	**0.9078**	**0.9163**	**1.0857**	**1.5223**	**1.6606**	**1.5736**	**1.2619**	**0.9691**

CONCLUSIONS

This paper presents a framework for prediction of alternative source energy using Monte Carlo method, which requires hourly average data. The load flow study on a real system indicates that the results of the actual values and MC values are almost matching. Hence this can be applied to any system irrespective of the size for prediction of loads using Monte Carlo as it is giving excellent results. Any number and type of resources may be added as long as the average input and output of the system are known.

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